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ABSTRACT

The four modes of cognitive preference are recall (R), principles (P), questions (Q), and application (A). The Science Cognitive Preference Inventory (SCPI) and an extensive background questionnaire were administered to 144 high school students from throughout the United States who were enrolled in various summer science programs for talented students. After six weeks the SCPI, which assesses cognitive preferences in biological and physical science, was administered again to some of these students. Forty other students were asked to respond to the SCPI and to explain their responses, which were classified according to empirical criteria by trained raters. High scores were found for P and Q and low scores for R, which indicates a high level of intellectual curiosity, a critical attitude toward scientific information, and a tendency to generalize findings into relationships and theories, rather than memorizing them. Comparison of the scores for physical science and for biological science showed that the R and Q modes are fairly consistent across disciplines but the P and A modes are not. Significant correlations of cognitive preferences with background factors and attitudes were found. (Author/EE)

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COGNITIVE PREFERENCES: A VALIDATION STUDY

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PRELIMINARY DRAFT

Abstract.

In 1964 Heath introduced the cognitive preference construct and used it to evaluate a new science curriculum. Since then the construct, adapted from research on cognitive styles, has been used in many research and evaluation studies. More recently, however, a number of questions have been raised concerning the validity of findings and analytical techniques employed in these studies (Brown 1975). Ultimately the validity of the cognitive preference construct itself is being questioned.

The objectives of this paper are:

a. To develop a framework for examining validity evidence for the cognitive preference construct;

b. To review the literature on cognitive preferences in the context of this framework;

c. To identify major validity questions to be studied;

d. To use the validity question to outline a series of validation studies;

e. To discuss the validity evidence developed in one recent study.

The Cognitive Preference Construct

In an effort to evaluate "new" science curricula, Heath (1964) introduced the construct of cognitive preference. This construct was based on the following differences that Heath suggested between traditional and "new" science curricula:

a. In the new courses emphasis was put on "a firm understanding of basic ideas that permeate the discipline rather than on technical vocabulary and practical applications" (see also Bruner, 1960).

b. New curricula have tried "to teach the students how to acquire, evaluate, and retrieve knowledge in a field and have devoted less energy to presenting him with a survey of this knowledge". In the

words of Hurd (1969): "An effort was made to minimize rote memorization of factual information and to emphasize concept formation, and understanding of scientific principles and theories".

From this Heath inferred that: "The interest is not in whether a student can identify correct and incorrect information, but rather what he/she is likely to do with the information intellectually". In other words the new curricula were aimed at influencing the way students tend to approach and process information, which may be compared with influencing the cognitive style or: "The mode of conceptual categorization of the environment" (definition of cognitive style in Kagan, Moss, and Sigel, 1963).

Heath identified the following modes of cognitive preference (adapted from Heath, 1964 and Tamir, 1975):

1. Factual information or Recall (R). Acceptance of scien tific information for its own sake, i.e. without consideration of its implications or application. A preference for recall indicates an interest in learning a name, a number, a definition, a formula, an observation, or a fact.
2. Principles (P). Representation or explanation of fundamental scientific principles or relationships. A preference for principles indicates an interest in identifying a relationship between variables, or a rule that can be applied to a class of objects, organisms, phenomena, or variables, or an interest in explaining phenomena.
3. Questioning (Q). Critical questioning of information for completeness, general validity, or limitations. A preference for questioning indicates an interest in critically analyzing and commenting on the validity of scientific information, and/or in generating suggestions and hypotheses for further research.

4. Applications (A). Application of scientific information in problem solving in real life situations. A preference for applications indicates an interest in using scientific information to solve problems in commerce, industry, farming, or in a person's daily life.

Heath's expectation was that students who had studied under the "new" science curricula, supported by the National Science Foundation (NSF), would tend to prefer generalizations and explanations (P) over factual detail (R) and practical applications (A). These students would also like to ask critical questions (Q). Students of traditional science curricula would have lower preferences for the (Q) and (P) categories and relatively higher preferences for the (R) and (A) modes of cognitive preference. Heath confirmed this hypothesis in his 1964 comparison between students in PSSC courses (Physical Science Study Committee, 1965) and traditional physics courses.

Measurement of cognitive preference.

In measuring cognitive preferences, students are presented with test items consisting of a stem with some introductory information followed by four statements. Each of these statements constitutes a correct continuation of the stem and represents one of the modes of cognitive preference. The following is an example from the Science Cognitive Preference Inventory:

> According to the atomic model of matter, the world is made of small particles called atoms. Atoms are built from protons, neutrons, and electrons.
>
> A. The atomic model has guided scientists and engineers to many discoveries.
> B. Physicists are searching for particles that are possibly more fundamental than protons, neutrons, or electrons.
> C. Over one hundred different atoms have been identified.
> D. The number of protons/electrons in an atom determines how this atom will behave (chemically) when it comes close to other atoms.

Statement A refers to applications of the atomic model (A- mode of cognitive preference), B indicates that our understanding of the atomic model

is not complete; there are questions to be answered (Q), C states a fact without much significance in itself (R), and D is an expression of a principle with wide ranging implications (P).

Students are asked to rank these statements 1-4 according to which statement they like most, second most, etc. The rankings for each mode of cognitive preference are totalled and divided by the number of items to define a score.

Construct validity.

A construct is a hypothetical representation of a piece of reality. Constructs are invented to introduce distinctions that are meaningful, which allow the formulation of expected relationships (hypotheses) that can be tested (de Groot, 1969). Constructs help people understand and summarize research and relate observable variables to each other and to other constructs. The cognitive preference construct is supposed to help us understand individual differences in the ways people process information. To assess the validity of a construct is to assess its potential for understanding, explaining, anticipating, and summarizing our observations of reality.

The construct of cognitive preference, like most other constructs, originated from a mixture of theoretical, pragmatic and common sense arguments. The theoretical rational came from the conceptual framework of "cognitive style". The pragmatic component came from the need to evaluate new science curricula that purportedly emphasized general principles, theories, and inquiry, rather than factual information and practical applications. The common sense support for the construct was the observation that some people are theory-oriented while others are more pragmatic; some people tend to question information while others tend to accept most of the information presented to them without questioning.

These same components, theory, pragmatism, and common sense, return at a more sophisticated level in the validation of a construct. Common sense provides the first hypotheses about the relationships of the construct with other constructs and with empirical variables. Gradually common sense becomes modified, rationalized, and incorporated into the theoretical network that will ultimately surround the construct. The pragmatic component is especially important in education. Educational constructs should have some kind of direct or indirect relationship with learning objectives and outcomes. A construct was defined as a hypothetical representation of reality. In order to be meaningful it has to be connected with other constructs in a theoretical framework. Operational definitions have to be developed in order to make connections with empirical variables. The construct and its empirical and theoretical network of relationships will ultimately be judged on their validity by the scientific community or forum (de Groot, 1969).

Validity evidence for a construct as well as for its operational definitions may be provided by (de Groot, 1967; Campbell and Fiske, 1959):

1. Internal consistency and stability of tests and other instruments that exemplify the operational definitions of the construct.
2. Logical consistency in the derivation of operational definitions from the construct (instrument validity only).
3. Correlation between different operational definitions of the construct.
4. Discrimination between the construct and other constructs.
5. Experimental verification of predicted relationships.
6. Replication of empirical findings in different populations and with different instruments.
7. The power to explain empirical relationships using the construct.

These categories of validity evidence will be used as an organizational scheme for a review of the literature on cognitive preference.

Validity of the Cognitive Preference Construct

1. Internal consistency.

Reliability coefficients of tests and other instruments are indicators of their internal consistency and stability. In the past reliabilities obtained for the various modes of cognitive preference have varied a great deal in different studies (Tamir, 1977a). At present some cognitive preference tests are available that have alpha Cronbach reliabilities of .8 or better for each of the modes of cognitive preference (Williams, 1975; Tamir, 1975; Tamir and Kempa, 1976). The possibility of reliable measurement contributes to the validity of a construct.

2. Logical consistency in the derivation of operational definitions.

In deriving an operational definition of a construct a number of steps have to be taken. With each step something may be added to or subtracted from the original meaning of the construct. In the process, additional sources of systematic variance may be introduced such as the language or format of a particular test.

Most studies of cognitive preferences have used ipsative data based on the students' ranking of four preference statements. The score for the fourth variable (for example, Applications) can be computed once the scores for the other three variables (for example, R, P, and Q) are known. The measurement of four variables is not independent. This lack of independence has important implications for the kind of statistical techniques that can be used to analyze cognitive preference data.

Use of statistical techniques such as correlation, analysis of variance and factor analysis would violate the assumption of independence of observations and could seriously distort the results of the analysis (Hicks, 1970; Clemans, 1966). Some researchers, however, have used a rating method in which students rate cognitive preference statements and which allows for ties. This method supplies normative data which permit the use of familiar statistical methods (Williams, 1975).

An experimental comparison of ipsative and normative scores and their relationships with other relevant variables has provided some answers as to the degree of distortion caused by the violation of the independence assumption (Tamir and Lunetta, 1977). However, low correlations between ipsative and normative scores raise the question as to whether or not ipsative and normative cognitive preference tests measure the same construct. A question that must be examined is which of the two methods best represents the intended construct?*

Brown (1975) pointed out the association of linguistic factors and specific modes of cognitive preference in most cognitive preference tests. Q-statements often contain a "?", or "it would be interesting", or "perhaps". A-statements include derivatives of the words "use" or "apply". Student responses to cognitive preference tests may be based on linguistic or other characteristics rather than on cognitive preference.

Other possible sources of systematic variance could be sought in reactions of students to cognitive preference tests. The instructions for the tests: "rank the statements following the descriptive information in each item according to your liking or interest" have been rather vague. At first students usually do not know what is expected from them, but after responding to a few items they usually seem to develop a consistent way of responding to the items. The rationales students use to explain their responses were investigated in this study.

3. Correlation between different operational definitions of the construct.

Only one method of measuring cognitive preferences has been used so far, though this method has been used with different kinds of subject matter. Alternative operational definitions will require more elaboration of the nature of the cognitive preference construct and its relationships to observable variables. More research is needed. An important question relating to the utility of the construct is whether preferences of people are related to their infor-

* A paper discussing this issue more extensively will be available in August 1978.

mation processing behaviors such as observing, predicting, hypothesizing, and other process skills, and to more complex cognitive activities such as writing laboratory reports and abstracting information from readings or other media. An exploratory study looking into this issue is underway and could generate some alternative measures of cognitive preference that could serve to establish correlative validity.

4. Discrimination between constructs.

Discrimination between the cognitive preference construct and other constructs must be clear if the construct is to have meaning in its own right. Furthermore there must be good discrimination between the modes of cognitive preference themselves.

In some studies high correlations have been found between P and R scores, indicating a poor discrimination between these variables on the particular tests used (Table 1).

The difference between the (high) P:R correlation in Tamir (1975) and Lunetta and Tamir (1977), and the (low) P:R correlation in Kempa and Dube (1973), and Tamir and Kempa (1976) raises the question whether the P-statements used in different test instruments were comparable. An analysis of the P and R statements of these test instruments has been planned and may provide more information about the nature of these modes of cognitive preference.

Strongly negative correlations have been found between Q and R scores, suggesting that Q and R may be opposite poles of a continuum (Kempa and Dube, 1973; Tamir, 1975). Factor analysis studies by these authors have supported this idea and often a Q-R score has been calculated and interpreted as a measure of interest in scientific information, or intellectual curiosity. Similarly a weak relationship has been found between A and P. A P-A score (Kempa and Dube, 1973) may possibly be a measure of a students interest in pure science as opposed to applied science. More research is needed to explore the

discrimination between P and R and to look into the relationships between Q and R and between P and A.

Correlations with other variables such as cognitive ability or aptitude and other dimensions of cognitive style have been rather low (Williams, 1975; Heath, 1964; Tamir, 1976) supporting the independent existence of the cognitive preference construct.

Two cognitive style measures may possibly be related to cognitive preference. Ausubel and Schwartz (1972) defined a generalizing-particularizing dimension. Generalizers were defined as people who tend to report generalizations in conveying information to others. Ausubel hypothesized that generalizers tend to encode particulars into generalizations. Particularizers were defined as people who tend to report particulars as such. The definition of generalizers resembles our definition of the P-mode of cognitive preference, while the definition of particularizers shows similarities with the R-mode. Siegel and Siegel (1965) introduced the construct educational set which divides learners into factually set learners and conceptually set learners. A factually set learner is predisposed to learn factual content. (S)he adds units of information to his/her cognitive structure without being driven to interrelate these elements into a contextual whole. A conceptually set learner rejects factual acquisition except as units of information are clustered and interrelated. (S)he prefers to learn concepts and principles. These definitions appear to be almost identical with the definitions of the P and R modes of cognitive preference. A study comparing Siegel's educational set with cognitive preference in being planned. It is hoped that such a study would clarify the distinctions between the P and R modes of cognitive preference.

5. Experimental verification of predicted relationships.

Once a construct has been conceived, predictions about its relationships to other constructs and variables are generated. Confirmation of such predictions provides strong evidence for the validity of the construct. At present there is a great need for theory development to elicit the nature of the cognitive preference construct and to predict relationships with other constructs. These relationships would include the influence of a student's cognitive preference on his or her information processing activities such as observing, classifying, predicting, inferring, hypothesizing, or abstracting, writing laboratory reports, digesting information from readings, experiments, or lectures, or other cognitive behaviors. If preference is related to the way we think, perceive, solve problems, learn, and relate to others (analog to Witkin's remarks about cognitive style, Witkin, 1977) these relationships need to be specified and tested. In a current study laboratory reports and notes of students are being rated for cognitive preference, their behavior during laboratory experiments is being observed, and the students are being tested for their understanding of processes of science. Correlations with scores on a cognitive preference test may provide evidence for relationships between cognitive activities of students and their (affective) cognitive preferences.

Influences of curriculum materials, teaching strategies, and teaching philosophies of science teachers on cognitive preferences of students have been predicted and in many instances confirmed. Heath (1964) found that PSSC (Physical Science Study Committee, 1965) students had higher preferences for P and Q and relatively lower preferences for R and A than students who had studied with more traditional curricula. In this study Heath provided support for the thesis that a curriculum emphasizing general principles and pro-

cesses for acquiring scientific information rather than factual knowledge and practical applications tends to produce students with relatively high P and Q scores. A study of PSSC by Mackay (1972) confirmed Heath's results. Other studies with the Chemical Bond Approach (Marks, 1967), CHEM Study (Atwood, 1967/68; Rogel, 1974), and the Biological Science Curriculum Study (Tamir, 1975; Lumetta and Tamir, 1977) partly replicated the trends observed by Heath. Tamir (1975) also showed the relationship between the teacher support for a curriculum and the cognitive preference of their students. Barnett (1974) and Schmedemann and LaShier (1967/68) found relationships between teacher characteristics and cognitive preference of their students.

Some evidence is available relating career choice and cognitive preference. Several studies (Williams, 1975; Tamir and Kempa, 1976) suggested that professionally or vocationally oriented students have higher A and lower P scores than liberal arts students and science majors.

Students with a high interest in science may be expected to have high Q and Q-R scores. This prediction was confirmed by a study of Lunetta and Tamir (1977) with a sample of high school students enrolled in summer science programs at the University of Iowa.

In subject areas that have a high relevance for the daily life of a student, such as human biology, students may be expected to have higher A scores than in less relevant areas. This was confirmed by Tamir (1975).

Replications of the studies reported under this category of validity evidence are needed since the evidence has not always been consistent (see the review of curriculum related cognitive preference studies in Tamir, 1977a).

6. Replication of empirical findings.

Experimental studies often provide results that were not expected. These results may be validated by replication after which explanations will have to be sought in the theory. Though cognitive preference scores have had low cor-

relation with aptitude (Williams, 1975; Heath, 1964), significant correlations have been found with achievement. High achievers had higher P and Q scores and lower R scores than low achievers. This made Tamir (1977b) suggest that cognitive preference may influence achievement.

7. The power to explain empirical results using the construct.

The possibility of explaining results including anomalies (unexpected results) using the construct is one of the strongest indications for its validity as is the lack of explanatory power of alternative constructs or theories.

Major validity questions

The review of the literature in the previous sections suggests the following validity questions that should be investigated:

a. What are the relationships between cognitive preference and cognitive functioning? Are students with a relatively high preference for P (compared with R,Q,A) better at recognizing and understanding of general principles and explanations in information presented to them than students with lower preference for P? Are students with high Q-scores better than others in doing research and critically analyzing information? Do high R/low Q students indeed represent the "memorizers"? More specifically: What relationships can be found between cognitive preferences or preference patterns and cognitive processes such as observation, classification, prediction, generation of hypotheses, analysis, interpretation and more complex activities such as writing laboratory reports or papers? In other words, does the construct describe what students are likely to do with information intellectually as Heath (1964) originally intended?

b. Do the few categories defined by Heath best describe cognitive preferences in science? Would refining or redefining the modes of

cognitive preference improve the discriminant validity and internal consistency of the categories, particularly of P and A?

c. Would it be possible to specify further the interactions of cognitive preference with instructional variables such as curriculum and teaching strategies in order to increase the "predictive validity" of the construct?

d. What are the implications of ipsative versus normative measurement procedures? Does each procedure measure a different construct? If so, which of the two constructs (ipsative or normative) has the most educational significance? If ipsative measurement is necessary, what are the consequences of violating the independence assumption in the statistical analysis of cognitive preference data?

Objectives for the experimental study

The objectives for the experimental study were to answer some of the validity questions raised in the previous section. Specific objectives were:

a. To replicate and extend a study of cognitive preferences of talented high school students using a different cognitive preference test (Lunetta and Tamir, 1977).

b. To explore the relationships between cognitive preference and attitude toward science.

c. To investigate the rationales students use to explain their responses to a cognitive preference test.

Methodology and design

The Science Cognitive Preference Inventory (SCPI) was administered to 144 science oriented high school students from throughout the United States who attended Secondary Science Training Programs at the University of Iowa

during the summer of 1977. These students were selected on the basis of interest and achievement in science and were certainly not representative for "the high school student".

The SCPI was administered on the first day of the summer program, together with an extensive background questionnaire. An attitude inventory was given to a subsample of 80 students. Six weeks later, at the conclusion of the program, the SCPI and the attitude inventory were administered to 73 students to assess test-retest reliabilities for the SCPI scales and to measure changes in attitude. Students participating in off campus environmental programs did not take the attitude inventory and the post-tests.

Two sections of high school students that had not participated in the study described above were asked to mark the most and least liked statements of SCPI items and to give a rationale for their choices. These rationales were classified according to a system developed after reading the responses of the first 12 students. The data presented in this study were based on the responses of 23 other students. The agreement between two "classifiers" was better than 80% for each of the categories of the classification system.

The cognitive preference test used in this study was the SCPI, a 30 item instrument developed by Tamir for assessing cognitive preferences of junior high and high school students. Each item of the SCPI consists of a stem or introduction with scientific information and four statements that are correct extensions of the stem. Each of these statements represents one of the modes of cognitive preference. Three judges (three graduate students, one of whom without an extensive science background) classified the statements using the definitions for R, P, Q and A given on page 2 of this paper. They obtained 100% agreement on 93% of the R-statements, 77% of the P-statements, and 100% and 87% of the Q and A-statements respectively.*

* For a more recent version of the SCPI these figures were: R-93%, P-90%, Q-100%, and P-87%

The students were instructed to rank the statements 1-4 according to their liking. Ties were not permitted, so after ranking three statements the ranking for the fourth was determined (ipsative measurement).

The SCPI contains physical and biological science items. Subscores for these areas are available. Alpha Cronbach (Cronbach, 1970) and test-retest reliabilities for this sample are presented in Table 2.

The background questionnaire assessed information on the student's sex, size of high school class, parents' education, science courses taken and grades earned, mode of science instruction, curricula and past research experience.

The attitude inventory was constructed according to a model by Klopfer in Bloom (1971) in a semantic differential format. A concept, for example "science" was followed by a polar adjective pair such as good . . .bad, or difficult . . . easy. The students were asked to indicate which of these adjectives best described the concept on a scale of 1-5. For scoring scale values were inverted so that high scores correlated with positive descriptors of the concept. The concepts used were: Science, Scientist, Research/Laboratory Work, and Expectations for the Summer Science Program. Subscores for each of these concepts were available as well as a combined score obtained by adding the subscores. Alpha Cronbach reliabilities are presented in Table 9. Statistical analysis was performed using SPSS programs.

Results and discussion

1. Internal consistency and stability.

The alpha Cronbach and test-retest reliabilities for the SCPI total and for the subtests are presented in Table 1. The reliabilities for the Recall (R) and Questioning (Q) categories were high for the total test as well as for the subtests supporting the validity of these categories. Reliabilities for the Principles (P) and Applications (A) categories were lower. Lunetta and Tamir (1977) using a similar sample but a different cognitive preference test obtained a similar pattern of reliabilities for R, P, Q, and A (.74, .62, .79, and .58 respectively, based on a 20 item test). The lower reliabilities of the P and A categories may be the result of poor items (agreement of judges on the classification of P and A statements was lower than on R and Q statements), or of poor validity of the P and A modes of cognitive preference.

Currently cognitive preference data from several studies are being reanalyzed. The P and A modes of cognitive preference have been divided into subcategories. Hopefully a comparison of the reliabilities of the subcategories will show a pattern that will suggest new definitions for the P and A modes of cognitive preference that will lead to higher reliabilities.

2. Logical consistency in the deriviation of the operational definitions.

Rationales provided by students for their choice of the least and most appealing statements were classified to: a) gain insight in the way students come to formulate response to cognitive preference test items; b) identify possible alternative sources of systematic variance in the SCPI. The classification criteria were developed after an analysis of the responses of the first 12 students. These responses were excluded from further analysis. The definitions of the categories and the results of the classification of the responses of 23 students are presented in Table 4.

The classification of P and R rationales was rather similar. This may be interpreted as evidence for poor discrimination between P and R. Based on the definitions of the modes of cognitive preference we would have expected marked differences. P-statements by definition represent principles, generalizations, and explanations that are relevant for science. It was expected that many students would rationalize their choice for a P-statement as most appealing by a reference to the importance of the statement. On the other hand few students were expected to use the category unimportant for least appealing P-statements. An opposite pattern was expected for R, since R-statements by definition represent information that is not generalizable

The number of rationales for least appealing R-statements classified as "Elementary Knowledge" was remarkably high. This raised questions about the interpretation of the R-category. Does a high preference for R indicate a preference for factual information that stands by itself and that is not easily generalizable (this is the common interpretation), or does it indicate a preference for <u>familiar</u> information? The results in Table 4 suggested the latter interpretation. The high number of P-rationales classified as "Elementary Knowledge" showed also that students tend to use the familiar-unfamiliar dimension in their judgement rather than an important-unimprotant dimension. The highly negative correlation between R and Q scores reported in the literature (Tamir, 1975; Rogel, 1974; Kempa and Dube, 1973; Tamir and Kempa, 1976) can be explained from this point of view. Q-statements contain suggestions for further research or critical questions about familiar information. A preference for Q may be interpreted as a preference for the unfa-

miliar and the opposite of valuing R (the familiar). These suggestions certainly need more exploration. The nature and size of the sample did not permit strong generalizations.

The classification of A-statements as practical showed that the students were able to distinguish the essence of an A-statement and that they can make a choice for applications when they have a preference for A.

Choices made because of the format of a statement (for example, because of language or because of the order of the statements in the item) would not be an expression of cognitive preference. The same may be true for the criterion of content where in a student rationalized his/her choice due to agreement or disagreement with the content of the item. If these sources of variance are systematic, for example, if certain language or format is correlated with one of the modes of cognitive preference, the validity of the preference inventory would suffer. For some modes of cognitive preference up to 50% of the rationales could not be classified.

3. Correlation between different operational definitions of the construct.

Only one cognitive preference instrument was used in this study. However, a comparison of the outcomes of this study with those of Lunetta and Tamir (1977) provided some evidence for this validity category. Lunetta and Tamir used the Biology Cognitive Preference Inventory (BCPI), while we used a different cognitive preference inventory. The samples used were very similar. In both studies similar score patterns (high Q, low R, see section 5), reliability coefficients, and low correlations with background variables were obtained, suggesting correlation between the two instruments and consistency in the cognitive preferences of the population of talented high school students.

4. Discrimination between the construct and other constructs.

In this study we focussed our attention on the discrimination between the different modes of cognitive preference rather than on differences with other constructs. Intercorrelations between SCPI scores and subscores are presented in Table 5. Correlations between ipsative variables (variables that are not measured independently from one another) do not follow the commonly used sampling distribution for correlations that has a mean of zero. The sampling distribution of correlations between four mutually dependent, ipsative measures has a mean of -.33 (Hicks, 1970). So correlations above -.33 are comparable to "positive" relationships and correlations below -.33 correspond to "negative" relationships. The correlation between the R and P scores (.45) was particularly high and one must raise the question as to whether the distinction between these categories was meaningful. The discrimination between R and P biology subscores was somewhat better, (.10), but on this form of the instrument the reliability for P-biological science was relatively low. The strongly negative correlation between Q and R scores suggests the possibility of a one dimensional trait with Q and R as poles. This relationship has been observed in many studies (Tamir, 1975; 1976; Kempa and Dube, 1973; Lunetta and Tamir, 1977; Tamir and Kempa, 1976). The correlation between P and A scores was close to -.33 indicating no relationship. It did not support the suggestion of Kempa and Dubé (1973) that P and A may be poles of a one dimensional scale that could be interpreted as a pragmatice versus theoretical, or an applied science versus pure science dimension.

Factor analysis, though a questionable technique for ipsative data (Hicks, 1970; Clemans, 1966), was carried out to facilitate comparison with other studies (Table 6). The first factor obtained from the varimax rotated factor matrix of correlations between subtest scores showed again the Q-R dichotomy and the P-R similarity. The second factor loaded strongly on A and somewhat on R, showing an R-A dichotomy rather than the P-A dichotomy which would have been expected from the literature (Kempa and Dubé, 1973; Rogel, 1974).

5. Experimental verification of predicted relationships.

Relationships were expected between the science cognitive preferences of students and the science curricula through which they had studied. Based on studies reported earlier in this paper, it was expected that students who had taken non-traditional science courses such as BSCS, CHEM Study and PSSC or Project Physcis would have a relatively lower preference for R and higher preference for Q than students who had taken more traditional science courses. Analyses of variance using the chemistry and physics curriculum respectively as independent variables and cognitive preferences (total as well as subtest scores) as dependent variables did not reveal any significant differences. This lack of measurable difference may be due to small sample sizes (PSSC-11, Project Physics-12, CHEM Study-11). Cognitive preferences of students who had taken different biology courses are presented in Table 6. Though statistical analysis did not reveal significant (.05 level) differences, trends are visible. Trends are in agreement with the finding of Lunetta and Tamir (1977) that students of the blue and yellow versions of BSCS tend to have lower preferences for R and higher preferences for Q than other students. Lack of significance may be due to the small sample size, or to small number of biological science items (17). On the other hand, results may also be interpreted as evidence of the failure of the construct to produce valid predictions. The weak relationship between curriculum and cognitive preference found in this and in other studies may also be explained by the wide diversity in the ways new curricula such as BSCS are being used in the classroom. Tamir (1975) demonstrated the interaction of the factors curriculum and teacher support for the curriculum. Other possible interactions of curriculum, teacher characteristics and teaching strategies will have to be explored to improve our understanding of the relationship between curriculum and cognitive preference.

6. Replication of empirical findings with different instruments and in different populations.

This study was a replication and extension of the study of Lunetta and Tamir (1977) in a similar population with a different cognitive preference instrument. As pointed out in section 3 both studies showed similar results in the score patterns, reliability coefficients, and low correlations with background variables.

The SCPI scores and subscores are presented in Table 3. The scores for the SCPI were standardized so that a random response pattern would lead to a score of 2.5 for each of the modes of cognitive preference. The low score for R and the moderately high scores for P and Q indicated that the students in this sample were critical toward scienctific information, interested in new information about science, and did not put much value on factual information by itself. This pattern replicated findings by Lunetta and Tamir (1977) and may be expected from talented high school students who chose to spend their summer vacation studying science. Subtests scores reflected the same pattern.

Unexpected male-female differences were found (Table 8). Females seemed to have a lower preference for P and a higher preference for A than males. Lunetta and Tamir (1977) did not find such differences in a similar sample. Tamir (1975) observed opposite trends in a sample of Israeli high school students. Replication will be necessary to clarify the relationships between sex and cognitive preference.

Low correlations of cognitive preference with background factors such as size of high school class, science courses taken, grades earned, size of the community of residence, and hobby were in agreement with the findings of Lunetta and Tamir (1977). Significant correlations ($p < .05$) were observed between high school status (sophomore, junior, senior, high school graduate) and R-total (correlation .24), Q-total(-.33), Q-physical science(-.31), and

Q-biological science(-.31). Apparently students with a lower high school status exhibited a higher degree of intellectual curiosity. (Intellectual curiosity has been shown to be related to the Q-R score) The reason for this relationship may be found in the higher admission requirements that exist for the younger students from lower grades.

Relationships of cognitive preference with the following variables had not been investigated before. Results need to be replicated and explained using the cognitive preference construct.

The correlations of cognitive preference and attitudes formed a clear pattern that was similar for pretest and post-test. Correlations of attitudes were significantly ($p < .05$) positive with the Q-scales and negative with the R-scales (Table 9). These results also need to be replicated with different attitude measures. A tentative explanation for the pattern of correlations that was observed, may be that a person with a high preference for Q and a relatively low preference for R is supposed to be curious and not satisfied with factual information. Such a person may want to know more and therefore identifies with the scientist who is continuously searching for new knowledge and new explanations. A low Q, high R person may be interested in certain facts in science but may not have a real desire to extend his/her knowledge, and this is not congruent with the image of the scientist. This explanation would account for the negative relationship between R-scores and attitude toward scientists. The pretest SCPI did not correlate with the Research/ Laboratory scale of the attitude inventory while the post-test scores correlated significantly. The instructional experiences of the students during their summer program differed markedly from their high school experience. As a result their perception of what research and laboratories were may have changed resulting in the post-test correlation pattern observed.

Though cognitive preferences (like cognitive styles, Witkin, 1977) are supposed to be relatively stable over time, changes could have taken place

because of the uniqueness of the experience for high school students who were familiar with high school science and teaching methods. Students in the research-participation program spent 100% of their time working in research laboratories under the personal guidance of a professor or research associate. Students in the course-centered physics-astronomy and computer science programs did not encounter modes of instruction that differed greatly from their high school experience. If there were to be any change, we would expect it to be in the direction of lower R and higher Q for the research-participation students based on the interpretation of the Q-R dimension as "intellectual" curiosity. A t-test for dependent samples showed the expected pattern (Table 10), but the probability of a chance event was still too high. The small sample size, a "ceiling" effect (high/low scores for Q and R to begin with) and the stability of cognitive preference may account for this result. Replication with a larger sample over a longer period of time could provide very valuable validity evidence for the cognitive preference construct.

Conclusions

The major conclusions and validity issues derived from a review of the literature and from the experimental study were:

a) The consistency of the results of this study with earlier studies and with those of Lunetta and Tamir (1977) have contributed to the validation of the cognitive preference construct. The consistency was particularly visible in the score patterns (high Q, low R), the pattern of reliability coefficients, and in low correlations between cognitive preference and background variables.

b) A major validity problem of the cognitive preference construct is the question of relationships with the cognitive functioning of students in tasks such as conducting experiments, reading, studying and summarizing information (currently, the authors are examining these relationships in another study).

c) Relationships between cognitive preference and other variables such as curriculum and instruction have not been consistent in all studies. A specification of intervening variables and further research are needed.

d) The study suggests that cognitive preferences may be changed (within a period of 6-8 weeks) through instructional strategies that are intensively research oriented providing students with opportunities to do research under the guidance of college professors.

e) A more thorough study of the implications of ipsative versus normative measurement is needed (a paper on this problem will be available in August, 1978).

f) The Q and R modes of cognitive preference seem to define a meaningful dimension of cognitive style as demonstrated by their reliabilities, intercorrelation, and relationships with other variables in the literature and in this study. Factor analysis and strongly negative intercorrelations between Q and R suggest that Q and R may be poles of one dimension that expresses intellectual curiosity. The significant correlation between cognitive preference Q and R scores and attitude towards science and scientists indicate affective characteristics of the Q-R scale. Information gathered, however, provides ample evidence that the scale has cognitive characteristics as well. Data collected in the experimental study indicated that the R mode may have to be interpreted as a preference for familiar information rather than for factual information. Such an interpretation would explain the Q-R dimension as a preference for familiar (R) versus unfamiliar (Q) information. That kind of interpretation would also explain the high correlation between P and R scores since the P statements in the instrument used in this study contained information that was familiar to most students. (Generally, rationales for student responses indicated that A and Q choices were <u>not</u> made on the basis of familiarity with the ideas. The interpretation of the Q-R scale as a measure of intellectual curiosity may be consistent with the interpretation of preference for unfamiliar-familiar information and ideas. Thus, high intellectual curiosity

would reflect a preference for new ideas.

g) The validities of the P and A modes of cognitive preference appear to be relatively weak due to lower reliabilities in their measurement as well as to high intercorrelations between P and R in several studies. A next step in the research is to analyze and compare cognitive preference instruments that have had high reliabilities for P and A with those that have had low reliabilities. The P and A categories may well need to be redefined.

Clearly, more research on the interpretation of the modes of cognitive preference is warranted at this time. Suggestions for the direction of that research have been developed within this paper.

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TABLE 1

INTERCORRELATIONS BETWEEN MODES OF COGNITIVE PREFERENCE

Mode of Cognitive Preference	Kempa/Dube (1972)			Tamir (1975)			Tamir/Kempa (1976)			van den Berg et.al. (1978)		
	R	P	Q	R	P	Q	R	P	Q	R	P	Q
Principles (P)	-.44			.45			-.09			.45		
Questioning (Q)	-.71	-.24		-.44	-.13		-.55	-.45		-.83	-.68	
Applications (A)	-.17	-.65	.24	-.44	.17	.33	-.48	-.57	.24	-.51	-.35	.10

TABLE 2

RELIABILITY COEFFICIENTS FOR THE SCIENCE COGNITIVE PREFERENCE INVENTORY

Mode of Cognitive Preference	Total Test			Physical Science			Biological Science		
	α Cronbach		Test-Retest[c]	α Cronbach		Test-Retest[c]	α Cronbach		Test-Retest[c]
	pre[a]	post[b]		pre[a]	post[b]		pre[a]	post[b]	
RECALL	.84	.84	.73	.57	.51	.62	.79	.81	.70
PRINCIPLES	.51	.54	.52	.41	.47	.43	.29	.18	.27
QUESTIONING	.88	.89	.74	.65	.70	.60	.81	.85	.74
APPLICATION	.58	.59	.53	.42	.43	.36	.45	.45	.48

a N = 144

b N = 73

c N = 63

TABLE 3

COGNITIVE PREFERENCE MEAN SCORES
FOR THE TOTAL TEST AND SUBTESTS (N = 144)

Mode of Cognitive Preference	Total Test		Physical Science		Biological Science	
	Mean	St Dev	Mean	St Dev	Mean	St Dev
RECALL	2.23	.49	2.30	.45	2.18	.58
PRINCIPLES	2.65	.25	2.55	.35	2.71	.28
QUESTIONING	2.63	.55	2.57	.51	2.68	.63
APPLICATIONS	2.49	.28	2.58	.35	2.42	.34

TABLE 4

CATEGORIZATION OF RATIONALES FOR COGNITIVE PREFERENCE STATEMENTS

CATEGORY	DEFINITION	PERCENT OF RATIONALES IN CATEGORY			
		R	P	Q	A
MOST APPEALING STATEMENTS:					
Practical	Student refers to practical value of a statement such as: "useful", "important for farmers".	9.4	9.1	9.8	45.8
Relevent or Important	Student refers to ~~relevance or~~ importance without indication of practical value: "important", "useful experiment to find out more about ..."	7.9	8.2	5.7	8.4
Interesting	Student indicates an interest in the statement: "interesting", "interesting that light can be an inhibitor".	4.7	5.5	20.3	9.6
Stimulating	Student expresses a desire to find out more about the information presented in the statement: "I would like to know ..."	6.3	12.7	26.0	3.6
Content	Student refers to the content of the statement and expresses agreement, disagreement, or adds information.	21.9	17.3	8.1	6.0
Other	Includes a number of categories that solicited low frequencies of responses, or did not seem to have any relationship with cognitive preference.	49.8	47.2	30.1	26.6
LEAST APP EALING STATEMENTS:					
Elementary Knowledge	Student refers to simplicity or triviality of the statement: "Obvious", "Everybody knows that", "Stupid".	40.0	38.2	11.9	26.1
Irrelevant or Unimportant	Student refers to the lack of significance of the statement: "So what", "Who cares".	21.2	9.2	16.4	5.4
Factual	Student judges the statement: "Too factual"	2.9	3.9	0	1.1
Not Interesting	Student judges the statement "Not Interesting", "Does not make me think".	5.8	2.6	6.0	8.0
Content	Student agrees, disagrees, or supplies additional information.	7.3	21.1	16.4	13.0
Other	Includes a number of categories that solicited low frequencies of responses, or did not seem to have any relationship with cognitive preference.	22.8	25.0	49.3	45.7

TABLE 5

INTERCORRELATIONS AMONG COGNITIVE PREFERENCE SCORES AND SUBSCORES (N = 144)

	Total Test			Physical Science			Biological Science		
	R	P	Q	R	P	Q	R	P	Q
P	.45			.45			.10		
Q	-.83	-.68		-.74	-.75		-.81	-.39	
A	-.51	-.35	.10	-.67	-.49	.24	-.28	-.27	-.16

	Physical Science with total	Biological Science with total	Physical Science with Biological Science
R	.88	.96	.70
P	.80	.82	.31
Q	.92	.97	.79
A	.77	.86	.34

TABLE 6

VARIMAX ANALYSIS OF COGNITIVE PREFERENCE SCORES (N = 144)

Mode of Cognitive Preference	Rotated Factor Loadings Factor 1	Factor 2
R Physical Science	.76	-.35
P Physical Science	.72	-.13
Q Physical Science	-.93	.11
A Physical Science	-.45	.65
R Biological Science	.74	-.38
P Biological Science	.31	-.16
Q Biological Science	-.95	-.02
A Biological Science	.06	.66
Percentage of Variance Explained	81%	19%

TABLE 7
COGNITIVE PREFERENCES OF STUDENTS GROUPED ACCORDING TO THEIR HIGH SCHOOL BIOLOGY COURSE

MODE OF COGNITIVE PREFERENCE	1. Modern Biology (N = 57)		2. BSCS Green (N = 10)		3. BSCS Yellow/Blue (N = 18)		Comparison 1-2
	$\bar{x}$	St Dev	$\bar{x}$	St Dev	$\bar{x}$	St Dev	t
R total	2.27	.49	2.15	.53	2.14	.39	-1.3
P	2.61	.24	2.78	.27	2.61	.28	
Q	2.60	.51	2.47	.63	2.73	-.56	1.0
A	2.51	.27	2.60	.19	2.52	.25	
R Biological Science	2.23	.59	2.18	.62	2.02	.42	-1.86
P	2.67	.23	2.85	.29	2.69	.33	
Q	2.67	.60	2.49	.78	2.84	.60	1.3
A	2.48	.42	2.48	.27	2.46	.29	
R Physical Science	2.33	.40	2.11	.48	2.31	.48	
P	2.54	.34	2.68	.26	2.51	.35	
Q	2.53	.46	2.46	.45	2.58	.56	
A	2.60	.34	2.75	.39	2.60	.31	

TABLE 8

MEAN OF COGNITIVE PREFERENCE SCORES OF MALES AND FEMALES

Mode of Cognitive Preference	FEMALE (N = 56) Mean	St Dev	MALE (N = 78) Mean	St Dev	t
P total	2.58	.23	2.69	.26	2.52**
A Physical Science	2.66	.29	2.53	.30	2.19**
P Biological Science	2.64	.26	2.76	.28	2.59**
Q Biological Science	2.78	.59	2.59	.63	1.80*
P-A total	.05	.41	.22	.45	2.35**
P-A Physical Science	-.15	.51	.06	.66	2.11**
P-A Biological Science	.19	.49	.34	.47	1.73*

* $p < .10$

** $p < .05$

TABLE 9

Correlation of cognitive preference and attitude scales

Mode of Cognitive Preference	Attitude Toward Science		Attitude Toward Scientists		Attitude Toward Laboratory/ Research		Attitude All Scales Combined	
	Pre-Test	Post Test	Pre-Test	Post Test	Pre-Test	Post Test	Pre-Test	Post Test
R Total		-.31	-.26	-.37		-.35	-.27	-.48
Q Total		.44	.29	.38		.33	.28	.51
R Physical Science	-.26	-.36	-.29	-.37		-.31	-.39	-.48
Q Physical Science	.24	.40	.25	.40		.34	.31	.51
R Biological Science		-.30	-.21	-.34		-.34		-.44
Q Biological Science		.42	.30	.34		.30	.25	.47
α Cronbach	.68	.61	.57	.63	.50	.51	.93	.87
Correlation Pre-Post	.59		.69		.14		.72	

*Only significant correlations, $p < .05$, are reported

TABLE 10

CHANGES IN THE COGNITIVE PREFERENCE PATTERNS OF RESEARCH PARTICIPATION STUDENTS OVER A SIX WEEK PERIOD (N = 28)

MODE OF COGNITIVE PREFERENCE	PRETEST		POST TEST			
	$\bar{x}$	St Dev	$\bar{x}$	St Dev	t	(2-tailed)
R total	2.13	.41	2.04	.46	-1.50	.15
Q total	2.78	.27	2.88	.26	1.34	.19
R Biological Science	2.11	.50	1.97	.57	-1.55	.13
Q Biological Science	2.82	.54	2.92	.68	1.08	.29
A Biological Science	2.71	.30	2.46	.28	-3.43	.002
P Physical Science	2.40	.33	2.52	.41	1.98	.058
A Physical Science	2.71	.30	2.53	.37	-2.07	.048